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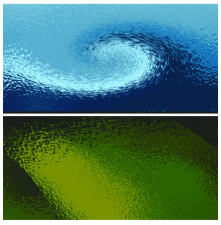

RESEARCH ARTICLE

Exotic species in Lesina and Varano lakes new guest in lesina and varao lakes: Gargano National Park (Italy)

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Abstract

1 - Introducing more or less voluntary alien species is now recognized worldwide as one of the most serious biological threats to biodiversity. The brackish-water lakes of the Lesina and Varano (Apulia, Adriatic Sea), where in recent years (2000-2007) the presence of exotic species is increasingly reported by local fishermen, have not been spared this phenomenon.

2 - The two biotopes are connected with the Adriatic Sea by two artificial channels. In this paper a list of alien species found in the two brackish basins in recent years was described.

3 - The following 6 species were reported: Oreochromis niloticus niloticus (Linnaeus, 1758) (Actinopterygii, Perciformes, Cichlidae), Callinectes sapidus (Rathbun, 1896) (Arthropoda, Crustacea, Decapoda, Portunidae), Procambarus clarkii (Girard 1852) (Arthropoda, Crustacea, Decapoda, Cambaridae), Musculista senhousia (Benson in Cantor,1842) (Mollusca, Bivalvia, Mytilidae), Rapana venosa (Valenciennes, 1846) (Mollusca, Gastropoda, Muricidae), Dyspanopeus sayi (Smith, 1869) (Arthropoda, Crustacea, Decapoda, Xanthidae).

4 - The presence of Oreochromis niloticus niloticus and Procambarus clarkii seemed to be linked to the accidental release from aquaculture activities present in the sourronding land, while the presence of Musculista senhousia, Rapana venosa and Dyspanopeus sayi was probably due to the introduction into the lake of the juvenile mussels coming from the northern Adriatic sea. The place of origin of other species is not clear.

Keywords: Mediterranean, Apulia, coastal ecosystems, exotic species, Lesina and Varano lakes.

Introduction

Ecosystems and their biological biodiversity are severely threatened by different anthropogenic phenomena which cause alteration of the original conditions of habitat. One of the most serious threats globally recognized for biodiversity is the introduction of exotic species (Genovesi, 2002), second only to the loss and fragmentation of habitats. Exotic species may affect native species through competition, predation and/or parasitism; however, habitat modification is one of the most important direct effects of non-indigenous species on native communities (Bertness, 1984; Simberloff, 1997). Recent studies showed that different species were deliberately or accidentally inserted in areas where they were absent (Drake, 1989; Sacchi *et al.*, 1989; Occhipinti-Ambrogi and

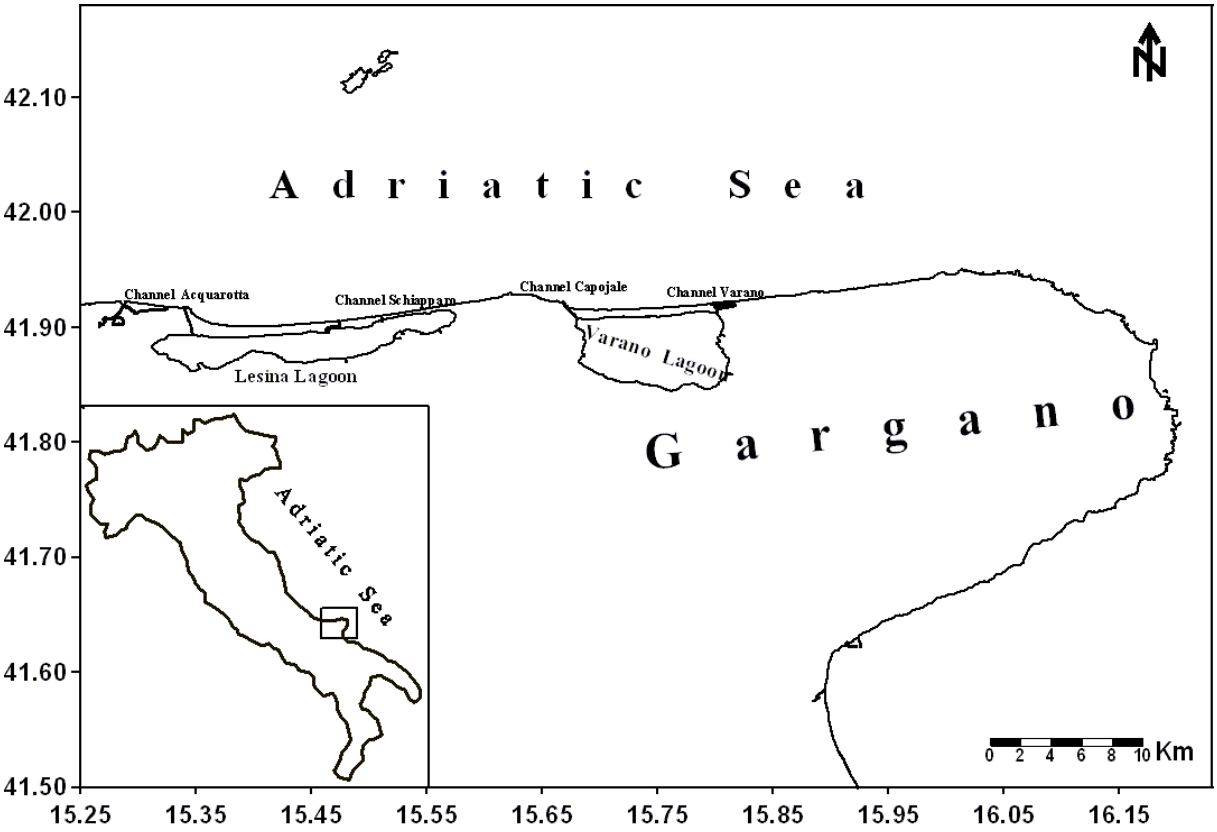

Figure 1 - Location of the two studied systems, Lesina and Varano lakes

Savini, 2003). In according to the definition of Zenetos (Zenetos *et al.*, 2005), the exotic species (or alien) are defined as species that are outside their natural distribution area and their invasions occur by human-mediated introductions (Carlton, 1996), while species that have spontaneously evolved and spread in a given area, without any human intervention, are called native species (or indigenous).

The brackish lakes of Lesina and Varano, located in the northern side of the Gargano promontory (Adriatic coasts, Fig. 1) and inserted in the Gargano National Park Territory, are the biggest brackish basins in the southern Italy.

Transport mechanisms of the alien species include fouling, aquaculture and fishing (Ruiz *et al.*, 1997). Both the Lesina and Varano lakes have a great economic relevance related to fishery and aquaculture activities and biological invasion of some exotic species has also affected these two basins, where in recent years (2000-2007) their presence was increasingly reported by local fishermen. The aim of this study is to report a list of exotic species in the two brackish basins and stress those species considered a potential threats for brackish water environments.

Materials and Methods

Study sites

Lesina lake

This ecosystem displays an extended and narrow shape elongated from east to west direction and it is connected with the Adriatic Sea by means of two artificial channels "Schiapparo" at the eastern side and "Acquarotta" at the western side. This ecosystem covers an area of 5,100 ha with an average depth of 0.8 m. The south-eastern side of the lake receives freshwater inputs which collect agricultural drainage waters from 2

pumping stations. The south-western part of the lake receives only waters drained by the intensive aquaculture farm (3 Km far from the lake). The low tide excursion occurring in the southern Adriatic Sea, the moderate freshwater input and the low efficiency of water exchanges with the sea suggest that the hydrological balance is strongly affected by atmospheric conditions. The lake exhibits strong seasonal variations of physical factors. Temperature ranges from 7°C in winter to 26°C in summer, and salinity between 11 and 34 psu; moreover, the western part of the lake generally exhibits higher salinity values compared the eastern area. (Manini *et al*., 2005a).

Varano lake

This brackish lake covers an area of 6,500 ha, with a perimeter of 33 Km. The average depth is 4 m, with a maximum value of 5 m in the central zone. The lake is surrounded on three sides by steep hills while the north side which faces the sea is a bar of sand dunes. Two artificial channels (Capojale and Varano) at the east and west extremities of the sand bar provide a connection with the Adriatic sea. Salinity values are relatively stable for a lake, never dropping below 20 psu. Temperature extremes are 5°C and 30°C. The hydrological system consists of the lake itself, two channels to the sea, freshwater inputs from a small catchment basin drained by the S. Antonino and S.Francesco torrents and the Muschiaturo drainage pumping station, and several stream springs (Bagno, Irchio, Ospedale, S.Nicola, etc.). The lake and the neighbouring coastal area are exploited by mussel farming, although such activity have been recently reduced within the lake, where the fishery is now the most important resource. Fish species are those typical of Mediterranean lakes: seabass, seabream, eel, grey mullet, etc. (Manini *et al*., 2005b).

Sampling and data analysis

Quatitative data shown in this work were collected within other projects aimed to study the environmental quality indicators, as the benthic macroinvertebrates and fishes and improve extensive aquaculture. From 2004 to 2007, a total of 53 sites in Varano lakes and 51 stations in Lesina basin were sampled twice a year using a box-corer (15x15x15cm) and the data from these samples were used to investigate both the abundance and biomass of the Japanese mussel *Musculista senhousia*. The other alien species listed in this work were monthly collected by catch with fyke nets in two sites of Lesina lakes only during 2007. Moreover, additional informations were occasionally culled from other sources, such as local fishermen and fisheries reports.

In the laboratory, samples for macrobenthic fauna were sorted, identified at the lowest possible taxonomic level, counted and weighted. For each sample caught by fyke nets, wet weight and total length were measured and the sex was identified, when possible. The wet weight was measured with a scale digital (accuracy of 0.01 g). The total length was measured using a digital calibre (accuracy of 0.01 mm).

Results

A total of 6 species were found in both the lakes; in particular 4 species in Lesina basin (1 Actinopterygii, 2 Crustaceans and 1 Bivalve) and 4 species in Varano basin (2 Crustaceans, 1 Gastropod and 1 Bivalve) (Table 1).

Exotic species list in both the lakes

Oreochromis niloticus niloticus (Linnaeus, 1758) (Actinopterygii, Perciformes, Cichlidae). This species was found only in Lesina basin and was collected by both the fyke nets and local fishermen during 4 sampling performed in 2007. It is important to highlight that only one individual was found in each sampling, except in October (2 examplaries). In Table 2, the total length, the wet weight and the sampling months

Table 1 - List of exotic species found in the two brackish lakes of Lesina and Varano.

Species	**Lesina**		**Varano**
Actinopterygii			
Oreochromis niloticus niloticus (Linnaeus, 1758)	+		
Crustacea			
Callinectes sapidus Rathbun, 1896	+		+
Dyspanopeus sayi (Smith, 1869)			+
Procambarus clarkii (Girard 1852)	+		
Gastropoda			
Rapana venosa (Valenciennes, 1846)			+
Bivalvia			
Musculista senhousia (Benson in Cantor,1842)	+		+

are summarised. Biometric data reported in this table showed that the lowest values of both length and weight (82 mm, 9.5 g) were measured in August, while the highest values (160 mm, 72.2 g) were obtained in April. In October the mean values of lenght and weight were 142 mm and 58.5 g, respectively.

Callinectes sapidus (Rathbun, 1896) (Arthropoda, Crustacea, Decapoda, Portunidae). This species was found in both the lakes, but biometric data are available only in Lesina basin, where the exemplaries ware caught by fyke nets. In Varano basin, its presence was indicated by local fishermen. A total of 5 individuals were collected during June, July and October 2007 and biometric data are presented in Table 3. In particular, the lowest values (carapace length of 74 mm, carapace width of 160.1 mm, weight of 204.9 g) were found in June and the highest ones (carapace length of 86 mm, carapace width of 196 mm, weight of 269.3 g) in October. The exemplaries were female and mature in all the study period.

Table 2 - Biometric measurements of *Oreochromis niloticus niloticus Linnaeus, 1758* caught in Lesina lake.

Period	**TL (mm)**	**W (g)**
April 16 2007	160	72.2
August 18 2007	82	9.5
September 13 2007	126	36.5
October 09 2007	127	44.5
October 09 2007	157	72.6
Mean	**130.4**	**47.06**
S.D.	**31.45**	**26.52**

TL = Total length; W = weight; S.D. = standard deviation

Procambarus clarkii (Girard 1852) (Arthropoda, Crustacea, Decapoda, Cambaridae). It was caught only in Lesina lake during some sampling performed from late winter and summer 2007. For each sampling, only one individual was found and both the biometric data and sex are presented in Table 4. The biomass ranged from 17.8 g (July) to 38.3 g (June), the mean total length was 105.02 mm (sd ± 21.56) with the maximum value (144.6 mm) found in June.

Rapana venosa (Valenciennes, 1846) (Mollusca, Gastropoda, Muricidae). This species was found only in Varano lake. A total of 6 species were collected by local fishermen, whose 5 specimens were found during 2006 and only one individual in 2007, even if information obtained by fishermen confirm

Table 3 - Biometric measurements of *Callinectes sapidus* specimens caught in Lesina lake.

Period	CL (mm)	CW (mm)	W (g)	Sex	Maturity
June 26 2007	74.0	170.0	220.1	Female	Yes
June 26 2007	74.0	160.1	204.9	Female	Yes
July 09 2007	78.0	178.8	257.0	Female	Yes
July 20 2007	78.0	168.5	247.7	Female	Yes
October 03 2007	86.0	196.0	269.3	Female	Yes
Mean	**78.00**	**174.68**	**239.80**		
S.D.	**4.90**	**13.64**	**26.62**		

CL = Carapace length (the distance between the center of the anterior interorbital margin and the center of the posterior margin); CW = = Carapace width (the widest point behind the posterior anterolateral spine); W = weight; S.D. = standard deviation.

Table 4 - Biometric measurements of *Procambarus clarkii* Girard*, 1852* specimens caught in Lesina lake.

Period	TL (mm)	CL (mm)	W (g)	Sex
February 15 2007	98.1	37.4	23.8	Male
March 30 2007	88.4	34.2	18.4	Male
April 16 2007	114	41.1	30.2	Female
May 31 2007	97	33	21.5	Male
June 26 2007	144.6	52.1	38.3	-
July 17 2007	88	33	17.8	Female
Mean	**105.02**	**38.47**	**25.00**	
S.D.	**21.57**	**7.37**	**7.91**	

TL = Total length; CL = carapace length; W = weight

that *Rapana venosa* was widely widespread and caught in the whole basin before 2006. Biometric values on collected specimens are indicated in Table 5. The maximum height (93 mm) was observed in both February 2006 and April 2007, while the minimum value was 57 mm in July 2006. In relation to the diameter, both the highest (79 mm) and lowest (57 mm) values were recorded during 2006 (February and July, respectively).

Dyspanopeus sayi (Smith, 1869) (Arthropoda, Crustacea, Decapoda, Xanthidae). Biometric data on this species are not available, but only informations about its presence was obtained by local fishermen, who confirmed the presence of *Dyspanopeus sayi* in Varano basin before 2006.

Musculista senhousia (Benson in Cantor, 1842) (Mollusca, Bivalvia, Mytilidae). This species was found for the first time in August 2004 in Varano lake and May 2005 in Lesina basin, during the macrobenthic samplings. Mean values of both abundance and biomass obtained during these periods were higher in Varano lake (29 ind/m^2, 5.20 g/m^2) than those measured in Lesina (7 ind/m^2, 0.17g/m^2). The presence of *M. senhousia* was subsequently confirmed in both the systems during the samplings of benthos performed in May 2006 in Varano (abundance of 28.18 ind/m^2, biomass of 5.53 gr/m^2) and April 2006 in Lesina basin (density of 16.22 ind/m^2 and a wet biomass of 4.61gr/m^2).

Table 5 - Biometric measurements of *Rapana venosa* (Valenciennes, 1846), specimens caught in Varano lake.

Period	H (mm)	L (mm)
February 2006	93	79
March 2006	83	67
July 2006	79	57
September 2006	91	60
April 2007	93	64
Mean	**87.80**	**65.40**
S.D.	**6.42**	**8.50**

H= Maximum height L= Maximum length

Discussion

Physically controlled environments such as harbour and brackish-water environments, are more prone to invasion than pristine sites. Previous studies reported that species invasions are facilitated in environments that are strongly depauperated and subjected to pollution (Galil, 2000; Occhipinti-Ambrogi and Savini, 2003). Native species might not be adapted to the changed environmental conditions, lessening their ability to reduce resource availability uniformly in time and space, and thus providing resource opportunities for invaders (Shea and Chesson, 2002).

Based on the species *Oreochromis niloticus niloticus***,** the first appearance occurred in Lesina lake in April 2007 and it was confirmed in the following period until late autumn (October 2007), while there was a complete absence during the winter months. It does not seem that the species prefers one particular area of the basin. Similar observations were also reported in a previous study performed in Lesina basin (Scordella *et al*., 2003). The presence of *Oreochromis niloticus niloticus* in Lesina lake could be linked to the accidental escapes of individuals along the discharge channels from commercial fish farms located in the southern area. *O. niloticus niloticus* is a species native of Africa, very resistant to diseases and characterized by high growth rates. This species is widely bred in fish farming in many countries in the Mediterranean sea as Israel, Egypt, Malta, France and Czechoslovakia (Welcommer, 1988).

In relation to *Callinectes sapidus*, a voracious predators, the first presence of this species was observed in both the systems during the summer season. In particular, in Varano basin the discovery of two exemplaries was made in summer 2007 by local fishermen, while in Lesina, the individuals were also found in October 2007. Moreover, from the localization of the fyke nets, it appears that the species were present above all in the central-eastern area of the Lesina basin. *C. sapidus* is a typical species active and abundant in shallow habitats along the Western Atlantic coast of North America and it is reported for the first time in Europe in 1900, along the French Atlantic coast, and later along the Netherland (Hartog and Holthuis, 1951) and Denmark (Wolff, 1954) that one. The presence in the Mediterranean sea has been proving since 1955 in Israel waters (Holthuis and Gottlibe, 1955). In Italy was reported in the gulf of Genoa (Tortonese, 1965) and in Sicily during 1970 (Cavaliere *et al.*, 1975). The first presence in the Adriatic sea occurred in Grado (Giordani-Soika, 1951), in Venice lake (Giordani-Soika, 1951; Mizzan, 1993) and in Ugento Lecce basins in January 2001. Crab carapace width is used to classify crabs as small (< 80 mm CW), medium (80–120 mm CW), or large (> 120 mm CW) (Harding, 2003). In Varano basin, adult blue crabs, with a carapace width higher than 160 mm, were collected for all sampling period.

R. venosa is a marine gastropod native of eastern Asia where it is used as a food resource. *R. venosa* is one of three species of *Rapana* in Chinese waters being native to the Sea of Japan, Yellow Sea, Bohai Sea, and the East China Sea to Taiwan (Tsi *et al.* 1983; Lai and Pan 1980; Harding

and Mann 1999). The introduction of *R. venosa* in the Mediterranean region (Black Sea) is suspected to have occurred in the 1940s (Drapkin, 1963). The first record in Italy occurred in the northern Adriatic sea (Ghisotti, 1971, 1974; Mel, 1976; Rinaldi, 1985; Bombace *et al.*, 1994), while a record from Elba in the Tyrrhenian Sea is provided by Terreni (1980). *R. venosa* is a novel prey for blue crabs (*C. sapidus*) and the resistance to predation by molluscivorous crustaceans depends on shell morphology. Rapa whelks with length less than approximately 35 mm are vulnerable to predation by all sizes of blue crabs (Harding, 2003), but in Varano lake mean sizes of 90 mm were observed for *R. venosa* and carapace width higher than 120 mm for *C. sapidus*, suggest that rapa wealks reduce their vulnerability to crab predators.

The red swamp crayfish, *P. clarkii,* is omnivorous species that may significantly affect benthic communities through complex lethal (consumptive) and nonlethal (behavioral) effects on other aquatic macroinvertebrates (Nyström *et al.*, 1999, 2001; Turner *et al.*, 2000; Usio and Townsend, 2002). It is a freshwater swamp which comes from the Southern United States and Northeastern Mexico. It was exported in all over the world because of its ease of breeding. This species tends to take the upper hand on other species present in areas where it was introduced to become the stronger ring of the ecological chain in the absence of natural predators. All this makes it very competitive. This decapode is well adapted to extreme environmental conditions, tolerating low oxygen concentrations and a wide range of water salinity (Huner and Barr, 1984; Claire and Wroiten, 1978). In Lesina lake, characterised by high seasonal fluctuations of environmental parameters, this species was found in the middle eastern area of the lake, where the salinity values are very low. After its introducing in Europe (Spain) in 1972 (Ackefors, 1999), *P. clarkii* spread rapidly across the continent for its remarkable capacity to disperse (Gherardi and Barbaresi, 2000). In Italy it was observed for the first time in Piedmont (Delmastro, 1992), while in Lazio, its presence was noticed in Rome and Rieti.

Dyspanopeus sayi (Smith, 1869) (Arthropoda, Crustacea, Decapoda, Xanthidae). It was found during a sampling carried out in June 2006, but already local fishermen reported this presence some time before. Exemplaries of *Dyspanopeus sayi* are now widely widespread across the lake. The introduction seems to be occurred as a result of the return to the lake of mussels farming activities. This crustacean is very abundant in ropes of mussels (*Mytilus galloprovincialis*), where it finds abundant food according to some authors (Landers, 1954; Mcdermott, 1960). *D. sayi* is a very common species along the American Atlantic coasts from Florida to Canada, where it get into the ports and estuaries characterised by sensitive variations of salinity and temperature, being able to stand temperature values particularly low. In Italy, the first presence of the species occurred in Venice lake during 1992 (Froglia, 1993; Mizzan, 1995).

Musculista senhousia is native to Asia, where it is found from the Siberian coast (Kulikova 1978, 1979), around the Malay Peninsula (Chuang 1961), and into the Red Sea (Barash and Danin 1971, 1972; Hoenselaar and Hoenselaar 1989). Within the last 70 yrs, this species has invaded the eastern Mediterranean via the Suez Canal (Barash and Danin 1971, 1972), and the south of France (Hoenselaar and Hoenselaar 1989). In Italy, it was unintentionally introduced in the early 1990s in the north-eastern Adriatic Sea (Sacca di Goro), and actually occurs with large populations also in Tyrrhenian (Gulf of Olbia) and Ionian (Mar Piccolo) coastal areas. (Mistri *et al.*, 2004). In both Lesina and Varano lakes, the species was introduced probably with species of economic relevance

and it was found both the ropes of mussels and the seabed, where it forms colonies of numerous individuals firmly anchored by the well-developed byssus. In regard to both the abundance and biomass, the results obtained in Varano lakes were higher than those observed in Lesina, even if increased values of density was observed in this last basin from 2004 to 2006. In addition, in Varano lake an extreme reduced abundance of *M. senhousia* with respect to the both western and eastern sides of the lagoon was observed during the summer sampling (August 2004), while increased abundance was observed again in the next sampling (May 2006). In summer, hypoxia and anoxia is known to greatly reduce *M. senhousia* abundance (Mistri 2002; Munari 2008). This results are consistent with those observed by Specchiulli (Specchiulli *et al*., 2008) in Varano lagoon.

Conclusion

The increase of aquaculture activities in recent decades has generally encouraged deliberate or accidental introductions of exotic species in aquatic environments. From this phenomenon, Lesina and Varano lakes have not been exempt. For these two basins, six exotic species have reported. It seems that these species all have a wide ecological range that partially overlap. They are particularly adaptable to great fluctuations of salinity, temperature and dissolved oxygen which characterise Lesina rather than Varano. These results could be considered as a preliminary survey for supporting further studies on the other exotic species in these two basins, including the relationship between predator and prey.

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